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APPENDIX J

AN INVESTIGATOR'S SUGGESTIONS FOR EFFECTIVE USE OF THE NASA JSC REDUCED GRAVITY PROGRAM KC-135A AIRCRAFT

This thoughtful narrative was compiled and submitted by Dr. Paul Ronney of Princeton University after his first flight week. Dr. Ronney has provided unusually insightful observations and detailed guidelines which should help the first-time flyer feel much more comfortable and prepared for his/her first flight week.

I. FOREWORD

This note is intended to be an informal compilation of (hopefully) helpful suggestions and information for first-time KC-135A users, particularly those from academic institutions or other research organizations having little or no previous experience in flight experiments. These observations are based on the author's experience during a week of flight tests sponsored by Marshall Space Flight Center during June of 1990. This note is not intended to be a reference manual; this document, or its revisions, should be consulted for a comprehensive description of the program before reading this note. Test Directors of the Reduced Gravity Office at JSC Ellington Field should be consulted for the final word on any aspects of the program.
[Test Directors note: Linda White is no longer with the Reduced Gravity Program; her replacement is Judy Rickard.]

II. INTRODUCTION

NASA JSC's KC-135A aircraft, based at Ellington Field outside of Houston, flies parabolic trajectories to obtain a reduced-gravity environment for about 25 seconds at a time. This environment can be used to study physical or biological processes which are thought to be affected by gravity. The KC-135A can and should be thought of as a "flying laboratory" where almost all common laboratory services are available or can be brought on board (e.g., electrical power, venting, vacuum, bottled gases, cryogenics, lasers, etc). A bewildering variety of experiments are routinely and safely performed on the KC-135A.

Once you've secured the necessary authorization to perform your experiments, you'll need to build and certify your experimental apparatus (or modify your existing ground-based apparatus) and obtain the required physical examination. These are discussed in Sections III and IV of this note, respectively, and the flights themselves are discussed in Section V.

You will probably interact mainly with Test Directors of the Reduced Gravity Program Office. Their main role is to serve the needs of the investigators while maintaining safe and efficient use of the aircraft. They wear many other hats as well. You will generally

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be sharing the aircraft with others, but Test Directors will try to accommodate your individual needs. They're very busy (they fly almost every day), but they welcome and encourage investigators to call them with questions. The ground crew that services the aircraft is very helpful as well.

The Reduced Gravity Office provides all services and equipment needed to fly the aircraft, but you are responsible for everything required to perform your specific experiment. The facilities at Ellington are limited, so bring all the ground support equipment, test samples, tools, spare parts, consumables, test equipment, etc., that your experiments require. Unless you've checked first, don't assume that something will be available at Ellington.

III. PREPARING YOUR EXPERIMENT FOR FLIGHT

A. Construction Suggestions

This document should be consulted for specifics on the facilities normally on the ground and in the air as well as the procedures and documentation required to obtain flight certification of your apparatus.

One of the best features of the KC-135A for low-gravity experiments is that it can be used very much like any other laboratory, albeit a rather crowded one. Many experiment packages look very much like they would in any laboratory except for greater compactness and some judicious padding. It is fashionable to use portable PCs with hard disks for data acquisition and ordinary consumer-grade video cassette recorders for video data. If your electronic equipment fits in standard 19" racks and doesn't consume a lot of power or do anything really scary, you're almost ready to start the certification process.

To pass the safety reviews, build or modify your apparatus with good old fashioned common sense in mind. Use sensible labeling on switches and indicators. Use color-coding on cables and hoses that could be crossed. Have interlocks on critical controls. Have a "panic button" to shut off or discharge your system if things get weird. Obviously, you'll have to have adequate equipment and procedures for handling any materials that are toxic, flammable, radioactive, etc. It is imperative that critical items are properly documented and tagged (e.g., pressure systems, high-voltage systems, lasers, and electrical fusing). Double-check that all your structural elements can handle the specified loads.

Your hardware will be bolted down on a 20" grid. If at all possible, keep your hardware less than 20" wide in one dimension and bolt on flanges to accommodate the 20" grid. That way it will be easier to maneuver your hardware past other equipment into and out of the aircraft. It will also be easier for people to walk past two pieces of equipment separated by one 20" grid unit if neither unit protrudes into the 20" gap.

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Don't worry too much about saving weight; the aircraft can carry A LOT of equipment (it's similar to a Boeing 707). If your apparatus is heavy, bolt on handles in strategic locations. If it's very heavy, bolt on wheels as well or at least bring a small dolly. With wheels and handles, people will be more likely to help you move your equipment. Also, keep fragile components and wiring well away from lifting locations. When people are straining to carry your hardware, they're less likely to be careful.

One case where you should be concerned about weight (and size) is if you decide to free-float a portion of your experiment. While this procedure yields a "cleaner" zero-g, the free-float time is usually limited to 5-10 seconds before the package bumps into the walls. You'll also require more space in the cabin, hence your flight opportunities will be more limited and more expensive. If you can live with the higher "g-jitter" experienced by bolted-down packages, do so. Refer to the next section for possible means of coping with g-jitter.

Many people will be walking or floating past your experiment, and they're usually in a hurry to get somewhere. Thus, protect exposed switches on your apparatus so that they will not be thrown accidentally. Use plenty of foam padding on your apparatus, particularly on sharp corners and edges. Bolt a sheet of Lexan or Plexiglas over your video monitor. Have adequate strain relief on your cables, hoses, etc., and route them so as to minimize the possibility of someone tripping on them or pulling them out accidentally. When in doubt, use more duct tape.

The most "mature" hardware frequently looks like an airline service cart with swing-out access panels (secured by quarter-turn thumbscrews) and handles in key locations.

If you use motors or other equipment with inductive loads that draw a large surge current when started, some means of keeping your power demands within safe limits will be required. Talk to Test Directors for suggestions. Also, if it's important that your power doesn't glitch when somebody starts their arc-welder (yes, arc-welders are flown), consider adding an Uninterruptible Power Supply to your apparatus.

Equipment such as vacuum pumps and gear motors that run in a bath of lubricating oil will have to be shut off and their vent lines closed during zero-g. Otherwise, the oil will flow out the vent during zero-g and be lost, possibly resulting in seizure of your equipment.

B. Procedures

Be sure you and your associates know your procedures backwards and forwards. Flight opportunities are limited, and flights go by very quickly, so rehearse and check, check and rehearse. Do plenty of ground tests so you'll know roughly what results to expect at low-gravity. Have a set of criteria for what does and does not constitute a failure which requires corrective action. Because you'll feel disoriented

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during your first few parabolas,^① keep the procedures as simple as possible. If your experiment inherently involves many steps, use automation to the extent practical.

With proper computer control, the checklist and procedures are built in; this maximizes the probability of success and minimizes the possibility of error or accident. Use fool-resistant prompting with messages like:

Ready to open vent valve - press ESCAPE to abort or any other key to continue

rather than

Press 'V' to open vent valve, 'A' to abort, 'P' to panic....

and have a displayed default value for every input prompt. To the extent possible, each operator should know each job in case one becomes incapacitated by motion sickness.

The first flight day will be chaotic. Do experiments using conditions on your test matrix that are "well-behaved." The learning curve is very steep; after a couple of days, you'll be able to do experiments in flight almost as easily as you could on the ground.

Construct your apparatus and define your procedures in such a way that you are not bound by one type of flight profile. Since you will probably be sharing the aircraft with others, generally you will not be able to dictate how many parabolas will be flown or the spacing between parabolas (but again, the Test Directors will try to accommodate your needs).

Due to unavoidable wind gusts and other factors, the "reduced gravity" will be closer to "zero-gravity" on some parabolas than others. If it is crucial that you start your experiment during a period of clean zero-g, some type of accelerometer system is recommended. Such a system is located near the aircraft center of gravity. Access to the analog signal is through any one of the six power panels distributed along the starboard side of the aircraft. [Test Directors' note: Two digital LED parabola counter/accelerometer displays are located on the front and aft bulkheads under the seat-belt signs for easy viewing from anywhere in the test area.] Another option is to add your own accelerometer package to your experiment. Using your own accelerometer would be the best solution if you need a precise record of the g-jitter, since it varies with location inside the aircraft. The poor man's solution to the g-jitter problem is to use a ping-pong ball on a string as an "accelerometer."

Hold the ping-pong ball in front of you and let go at the start of the trajectory. When the ball is motionless or moves at a constant speed, the gravity level is very low.

^① At zero-g, many people sense that they are on their backs looking up at their experiment, which makes it difficult to focus on a busy, complex display.

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C. Safety Reviews

Flight safety is the main concern of most of the JSC personnel with whom you will interact. Your equipment will have already passed at least one safety inspection before reaching the buildup room at Ellington (Building 993), either at JSC or your sponsoring NASA center. The final safety review is performed at Ellington and is called the Test Readiness Review (TRR). The TRR is usually performed the day before your first flight, or perhaps the morning of your first flight. There will be about 7 or 8 people present, including you. The review committee's main job is to ensure that your apparatus and procedures are safe, not to ensure that it works well or will yield good scientific results. (Presumably if you've gotten this far, you've worked out the latter two.) They're firm but reasonable; they're not trying to find some flimsy excuse to ground your experiment. If you've followed the guidelines in this document and properly documented everything, you shouldn't have reason to sweat more than three or four bricks during the TRR.

The importance of proper documentation, certification, and tagging of critical items cannot be overemphasized. The author's experience was that most experimenters had equipment that was intrinsically safe, but some had not done their homework to demonstrate and document that fact to the TRR committee's satisfaction.

IV. PREPARING YOURSELF FOR FLIGHT

Another advantage of the KC-135A for low-gravity experimentation is that usually the most qualified person can perform the experiment, and he or she needs very little specialized training to qualify for a flight. Good physical condition is helpful but not essential. The FAA Class III can be given by an FAA-certified physician (call your local general aviation airport for a list). Be sure to get the documentation for your test personnel to the Physiological Training Officer as early as possible.

Director's Note: The documentation for your test personnel needs to be sent to the Physiological Training Officer at JSC, Code SD25/KS at least 3 weeks (F-3 weeks) prior to the first flight.

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V. FLYING YOUR EXPERIMENT

A. Arrival Day

On your arrival day (usually Monday) you'll go to Ellington Field (see the enclosed map), pick up your security badge at the NASA gate, and go down to Hangar 990 where the aircraft is kept. The buildup/work area for experiments is the adjacent building numbered 993. Ask the Test Directors what floor space you can use. If you need a forklift to unload, ask them. Set up your flight hardware on the floor in approximately the same configuration as it will be on the aircraft. Connect AC power and check that your equipment survived the journey to Houston.

Your TRR will probably be sometime the morning of the day before your first flight. The committee will ask you to briefly describe your experiment, then they'll look over your equipment and start asking questions. Be straight with them. The process may take anywhere from a few minutes to an hour depending upon the complexity and hazards of your experiment. Be prepared to make any modifications they specify.

In the afternoon your equipment will be loaded into the KC-135A using a forklift. Help others carry and move equipment around and the whole process will be much smoother and quicker. Bolt down your equipment with the bolts provided. Connect your AC, gas hoses, vent lines, etc., and secure them with--what else--duct tape. Power everything up and check out your equipment thoroughly TODAY--"in-flight debugging" is unfashionable and usually unsuccessful.

Now is also the time to consider whether or not you will need to be secured in some way to operate your experiment during the flight. If you must remain in one place and have nothing to brace against or wrap your legs around, ask one of the Test Directors for a couple of O-rings to attach to the floor and plan on bringing a bungee cord. Otherwise, it's probably best just to free-float. Too many restraints just get in the way.

B. Things to Bring On Board

Bring everything you need to Houston, but bring a minimum amount of equipment on board. The following generic flight equipment is highly recommended:

- Duct tape
- Duct tape
- Duct tape (get the message?)
- Flashlight
- 9/16" socket and open-end wrench (for bolting your package down)
- Cable ties
- Sticky-backed Velcro strips (to secure keyboards, clipboards, personal cameras, etc.)

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“Bungee” cords
 Screwdrivers
 Scissors and carpenter’s knife
 Pliers and wire cutters

Have a small drawer or pouch in your apparatus for this generic equipment and your experiment-specific items. Don’t plan on doing repairs during the parabolas if something goes wrong; it’s difficult to do and the constant head movements required are a good way to induce motion sickness. Instead, have predefined contingency procedures for operating your experiments in manual mode or at reduced capacity if one part of the apparatus quits.

C. Flight Day

You should arrive at Building 993 at 7:30, or earlier if you need time on the plane before the flight. The mandatory Pre-Flight Safety Briefing is given at 8:15 and discusses the do’s and don’ts of flying zero-g, as well as emergency procedures. After the briefing, you will be issued a flight suit and boots. Dress light in summer as Houston weather is usually hot and humid. A T-shirt and shorts under your flight suit will be fine.

You’ll sit in airline-style seats in the back of the aircraft during takeoff. It’s frequently very hot until the plane takes off and the on-board air conditioning kicks in. Also, there are almost no windows on the plane. This is a bit disconcerting at takeoff, but during the parabolas it’s just as well that you don’t see the peculiar attitudes the aircraft assumes.^② Shortly after takeoff you’ll be allowed to get up and go to your experiment while the aircraft flies out over the Gulf of Mexico. Turn on your equipment and let it warm up. It’ll be about 20 minutes before the first parabola, but get everything set up now for the first test.

As the time nears, the pilots will be adjusting speed and pitch attitude to set up for the first trajectory. As a result, you’ll probably feel some “false alarms” when you think the first parabola is beginning, but there’s no mistaking “the real thing”. You’ll feel pressed into the floor, your face will feel heavy, and you’ll sense that everything around you is falling; that’s the 2-g pull-up. After 10 or 15 seconds, there will be a sudden release as you’re literally thrown into zero-g. You’ll find yourself floating and experiencing a most disorienting, bizarre, yet wonderful sensation.^③ The aircraft becomes strangely silent at this point, since it, too, is weightless; the

^② If you have an intermission in your experiment, ask to sit in the cockpit for a few parabolas so you can see just how peculiar the attitudes are, or just look out one of the hatch windows.

^③ After getting off the aircraft, comments like the following are sometimes heard: “... it’s better than (such-and-such)... WAY better...”.

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only thrust needed is that to overcome drag. After about 25 seconds, during which (unbeknownst to you) the aircraft has gone from a 45° nose-up to a 45° nose-down attitude, zero-g is abruptly terminated by the pull-out, and you're back at 2-g. After a brief period which feels like 1-g, the roller-coaster ride repeats. A typical flight profile might consist of 5 to 10 parabolas in a row followed by a few minutes of 1-g, followed by another set of parabolas, and so on, based on user requirements.

D. Getting Sick

Nearly everyone will experience at least moderate nausea on their first flight; however, the response varies drastically with the individual. Throwing up is perfectly acceptable, so accept the prospect. The motion sickness that most people experience is not debilitating, and if you do feel nauseated, you'll feel much better after getting sick. The Test Directors will describe the proper procedures for using airsickness bags. Nearly everyone will experience at least moderate nausea on their first flight; however, the response varies drastically with the individual.

Eat light the night before and the morning of your first flight. Don't fast—you'll want to have something in your stomach if you do get sick. Oranges are held in high regard by new and frequent flyers. Bananas seem to work well also; eat some before your flight. Avoid milk.

If you desire, you can probably get anti-motion sickness medication. If you want to take the medication, see one of the Test Directors, who can authorize the Clinic to dispense it to you. The medication is strong, and some people do not like the side effects. The general consensus the author found was that it's probably better to not take the medication and get accustomed to the flights through "natural" means.

To minimize nausea, try the following approach. During your first, say, 10 parabolas, just stare straight ahead at your equipment. Make as few movements as possible consistent with the requirements of your experiments and, especially, don't move your head during the 2-g pull-ups and pull-outs. If you must look around, move your whole body, not just your head. Don't try to float during zero-g at first; instead, hold yourself in place—it's very easy. If you feel okay after 10 parabolas, let yourself float upward at zero-g, but don't fly, and keep yourself oriented the "right" way with respect to the cabin. After another 10 parabolas, if you still feel okay, then go ahead and float upside down, do somersaults, etc. Be careful during your first "Superman" flight—you're likely to become very disoriented. And never free-float above or near equipment—a sudden burst of turbulence or an unexpected pullout could slam you into something hard.

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E. A Typical Daily Schedule

Every day is different, but the following generic schedule can be used as a rough guide for planning purposes.

- 6:30 Arrive at Building 993.
- 7:00 AC and DC power available in aircraft. Board aircraft and begin pre-flight checkout of apparatus.
- 8:15 Safety/Orientation video in briefing room.
- 8:30 Issue of flight suits, boots and air sickness bags.
- 8:45 Pilot briefing on first flight day.
- 9:00 All non-flight personnel deplane.
- 9:30 Aircraft takes off.
- 9:45 Aircraft arrives at test range over the Gulf of Mexico. Low-gravity maneuvers begin.
- 11:15 Low-gravity maneuvers end.
- 11:30 Land at Ellington and go to lunch. Aircraft is refueled – no access to aircraft.
Last flight day: strip and unload aircraft before refueling.
- 12:30 Access to aircraft available – power available – change out/adjust apparatus as needed.
- 3:00 Power off – all personnel must deplane.
- 4:00 Buildup area (Building 993) closes.

Generally when the aircraft is available for boarding, there is AC and DC power available from a ground generator. Mercifully, there is usually air conditioning available from a ground unit when needed.

VI. CONCLUSION

The KC-135A aircraft provides a unique opportunity to do research on low-gravity phenomena at reasonable cost in a “hands-on” environment. It is an example of “small science” that works. It works mainly because of the efforts of a small but dedicated and enthusiastic group of people. Share their sense of team spirit, help others, use common sense, and do good research!

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